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MARCH 6, 1989

CHEMICAL & ENGINEERING

NEWS

Expedition uncovers threat to Arctic ozone
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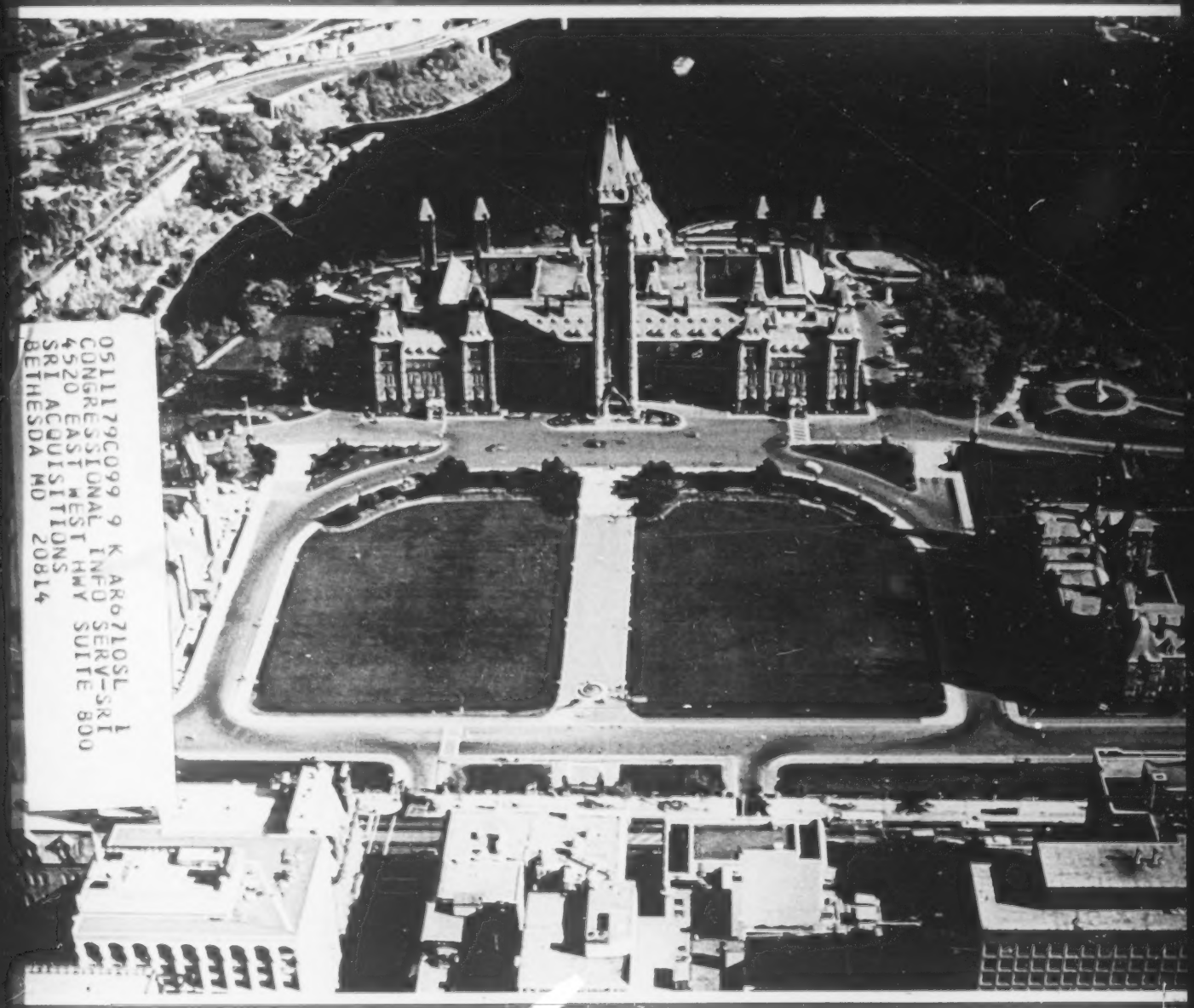

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Science in Canada

Struggling for a policy Page 7

CHEMICAL & ENGINEERING
NEWS

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MARCH 6, 1989

News of the Week

■ **Four former Du Pont employees are arrested for alleged $10 million extortion threat relating to theft of trade secrets on spandex fiber production.** Page 4

■ **Three chemical engineers are convicted of illegally storing, treating, and disposing of hazardous waste at Aberdeen Proving Ground in Maryland.** Page 4

■ **Catalytic antibody that catalyzes hydrolysis at a specific site in a peptide is developed by scientists at Research Institute of Scripps Clinic, La Jolla, Calif.** Page 5

■ **Morton Thiokol announces intent to divide current firm into two new companies, Thiokol Corp. and Morton International.** Page 6

■ **NRC review of literature on links between diet and disease leads to recommendations for changes in the American diet.** Page 6

Cover: Canada's Parliament Buildings in Ottawa. Photo courtesy of Canadian Embassy, Washington, D.C.

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Perkin Medal

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Chemical & Engineering News

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LETTERS

Biodegradation of PCBs

SIR: I read with interest your article on biodegradation of PCBs (C&EN, Nov. 21, 1988, page 5). However, it was incorrect to report that "heavily substituted polychlorinated biphenyls (PCBs) . . . have now for the first time been proven to be biodegradable."

I conclusively demonstrated biodegradation of heavily chlorinated biphenyls in 1985 using a mixture called Aroclor 1254 (54% chlorine by weight with between 4 and 7 chlorines per molecule) [*Enzyme Microb. Technol.*, **7**, 194 (1985)]. These experiments showed that *Phanerochaete chrysosporium* and other wood decay white-rot fungi are able to mineralize highly chlorinated PCBs. The degradation of [U-^{14}C]-Aroclor 1254 resulted in irreversible binding to the cells, release of water-soluble degradation products, release of $^{14}CO_2$, and disappearance of the gas chromatographic peaks.

David C. Eaton
Science & Technology Department
Hercules Research Center
Wilmington, Del.

Nuclear power

SIR: Mike McCormack (C&EN, Dec. 12, 1988, page 2) correctly identifies antinuclear activism as antienvironmentalism. Results of real antienvironmentalism are part of the scenery across Pennsylvania, West Virginia, eastern Kentucky, or southeast Ohio, where prime forestland has been, and continues to be, destroyed by coal mining, and in southwestern Indiana, where some of the country's most beautiful farmland is being turned into sterile piles of rubble and lifeless pools by strip mining. The antinuclear (actually antiscience) faddist assumes that stripping or undermining of farm and forestland is environmentally benign, naively believing that this despoiled land can be restored to pristine condition. Strip mine damage is forever: The land is ruined, toxic elements that had been tied up for geologic ages are released into groundwaters, and the burning coal releases these same toxic elements into air and land. Note also the loss of life in coal mining: more than 270,000 since 1900 in this country alone, plus innumerable cripplings from accidents and black lung. Of course, to the antinuclear activist this mass of deaths and cripplings is boringly commonplace, infinitely less titillating than any harmless reportable event at a nuclear power plant.

The problems of radioactive waste are political, not technical. We actually are more capable of handling radioactive waste than we are of protecting ourselves from fossil fuel wastes and from the effects of so-called renewable energy sources. Years of research and development have been well spent on methods for containing reactor waste. Years of controversy have also been wasted on where to dispose of nuclear waste. Scientific methodology—it is well known that answers fall out quickly once the right questions are asked—would replace, "How do we get rid of these radioactive wastes?" with "What can these wastes be used for?" After all, they contain a considerable quantity of usable low-grade energy. As added bonuses, by using this energy, we will always know where it is, and save further energy by avoiding expensive studies on ill-conceived disposal schemes.

Coal is a dangerously polluting energy source, and low-density energy sources—wind, water, wood, and refuse—cannot sustain an industrial society. We need vast amounts of power for running industry and households, and for purifying contaminated water and seawater for current needs and for reclamation of salinated lands. Because nuclear energy is the most controlled and controllable of all high-grade energy sources, it is the cleanest. High-density power sources other than nuclear will pollute the environment faster than it can be repaired.

In antinuclear propaganda, the following clichés are staples: "waste that will remain dangerously radioactive for N-thousand years"; "Why don't you tell us THE solution?"; and "Our descendants N-generations from now will bitterly curse us." The first cliché shows neither understanding of the physics of radioactive decay nor that radioactive elements follow rules of chemistry. The second cliché is expected from the nonscientist; from those with scientific training we should expect, "What are viable alternatives (if a real problem exists) among many proposed partial solu-

Continued on page 55

Correction

• Feb. 27, page 76: The Perrier Group's plant near Nîmes, France, produces a billion bottles a year of Perrier water, equivalent to more than 500 million L of water, not 500 L of water.

Canada Grapples with Its Science and Technology Policy

Debate persists between government and scientific community over whether country has a policy in place, but government is focusing more attention on research and technology and has taken some key steps

Earl V. Anderson, C&EN Northeast News Bureau

Following last November's convincing election victory, Canada's Prime Minister, Brian Mulroney, and the Progressive Conservatives are safely entrenched on Ottawa's Parliament Hill, preparing to lead Canada for another few years. One of the toughest jobs facing them when Parliament reconvenes late this month or in early April is coping with a budget deficit that, relatively speaking, is larger than that of the U.S.

Meanwhile, a new federal department—the Department of Industry, Science & Technology Canada (ISTC)—is being set up. A blend of the old Department of Regional Industrial Expansion and the Ministry of State (Science & Technology), ISTC has been taking shape ever since Mulroney announced its establishment in August 1987, although legally the department doesn't yet exist. Enabling legislation was sidetracked by last year's election but likely will be acted upon soon.

Just last month, as part of a major cabinet reshuffle, William C. Winegard became the new Minister of State (Science & Technology), replacing Frank Oberle, who had held the post during some trying times for Canadian science and technology policy. He will report to Harvie Andre, who will replace Robert R. de Cotret as head of the new ISTC.

All of these developments are certain to have an impact on Canada's science and technology policy. And scientists throughout Canada—in universities, industry, and government itself—are watching anxiously to see just what kind of an impact it will be.

That's because Canadian science policy is at a delicate and crucial crossroads. But then, Canada itself is at a crossroads. As the industrialized world becomes increasingly competitive and as more and more countries rely on advanced technology to maintain a sharp competitive edge, Canada has been undergoing an intensive self-examination.

Based on years of study after exhaustive study, it

National Research Council of Canada photo

has become almost axiomatic now among leading Canadian industrialists, academics, and policymakers that Canada no longer can depend solely on its natural resource-based industries to carry the country into the high-tech 21st century. Most of them agree that Canada has to shake its old image as a "carrier of water and a hewer of wood." Canada's people—and their knowledge—now have become recognized as the crucial resource needed for the country's future economic growth.

That means hitching Canada's wagon of international competitiveness to a horse of excellence in science and technology. In their first four years of office, Mulroney and the Progressive Conservatives have done a lot to pry such ideas out of the closet and into the public arena. But that does not solve the problem; it only underscores the fact that a problem exists.

Photo by Bill McCarthy

Prime Minister Mulroney (center) tours Canadian chemical plant

Critics contend that there has been more rhetoric than action on science policy in Canada over the past few years. There is a degree of truth in that. But in many cases, the criticism reflects their belief that government simply has not pumped enough money into science and technology, or that the money could have been better spent on their projects instead of someone else's.

In fairness, the Mulroney government has provided more leadership and has given science and technology more attention than has been witnessed in Ottawa for many years. And there's little doubt that it has taken some significant steps to enhance science and technology in Canada.

But does that mean that Canada now has a definitive science policy solidly in place? It's not a facetious question. Many within the Canadian scientific community wonder about it openly. The answer depends upon whom you ask. Government officials involved in science and technology tell you emphatically that Canada, indeed, has a science policy. Not yet, say many individuals in the scientific community. It's still evolving.

The discord in Canada over science and technology policy is obvious. But whether such a policy does indeed exist is a tough question to answer. In part, it's tough because a lot depends upon what is meant by "policy." Geraldine A. Kenney-Wallace, a professor of chemistry and physics at the University of Toronto and, since late 1987, chairman of the Science Council of Canada, says that "policy is creating a climate in which things can get done." The Science Council is an arm's length advisory organization in the federal government.

For many years, she says, that climate hasn't been conducive to Canadian science and technology. But she thinks that over the past few years the climate has been changing substantially—and for the better. However, reverting to science-speak, Kenney-Wallace says, "We have not yet made the phase transition into a new era where science and technology are regarded as intrinsic parts of our economic and social fabric." Few Canadian scientists will disagree with that.

Nor does anyone doubt that what Mulroney's administration does during its present tenure in Ottawa will help decide whether Canada makes that phase transition. Canadian culture and cultural politics, unique among industrialized countries, will come into play. The seemingly endless debates about the relationships between science and government, between universities and industry, and between federal and provincial governments no doubt will continue. Different factions within Canada's scientific community will argue about the how and the how much. But more than ever before, there is a growing consensus that decision-making time has arrived.

Consensus building, in fact, has been a major part of Mulroney's science effort in his first tour of duty in Ottawa. And with very little dissent, there is a general consensus now that Canada will have to get its science and technology act together if it hopes to remain a strong competitor in the world marketplace.

For Canada, the bottom line is that it does not do enough research and development, not enough technology, not enough innovation. In short, Canada doesn't spend enough money on science and technology.

For this, government blames industry. Industry, in turn, blames government. They are both right.

By most measures, Canada does much less R&D than most of the industrialized countries that are—and will continue to be—its competitors. One popular measure is gross expenditures on R&D as a percentage of gross domestic product. According to the Organization for Economic Cooperation & Development (OECD), which compiles these data, Canada spends only 1.43%

of its gross domestic product on R&D. That puts Canada 10th in a list of 11 countries.

Audrey Doerr, director general of the federal research branch in ISTC's science sector, echoes what many Canadians believe in saying that such yardsticks may not be the best measure of science and technology in Canada. With its small population and an industry structured heavily in the natural resources, it's not unreasonable to expect Canada to rate low in such measurements.

Others say that measuring R&D spending as a percentage of gross domestic product says little, if anything, about how well research is converted into useful innovations by industry. They think that economic, political, and social factors play a far greater role in economic growth than simple percentage measurements of R&D spending.

Nevertheless, one reason for Canada's poor showing is that Canadian industry is a notoriously poor performer when it comes to science and technology. Looking at industrial spending alone, Canada again ranks 10th out of 11 countries, with its industry spending only 0.65% of industrial domestic product on R&D.

It's tempting to say that the government's dollar commitment is high compared with that of industry in Canada. Government, after all, does fund about 60% of all R&D in Canada, compared with roughly 40% by industry. But it's not high compared with other countries. On that score, Canada ranks dead last on the OECD list of 11 countries. Government spends only 0.58% of gross domestic product on R&D.

Fewer than 5% of all Canadian companies do the bulk of the industrial R&D in Canada. About three fourths of the companies do no R&D at all.

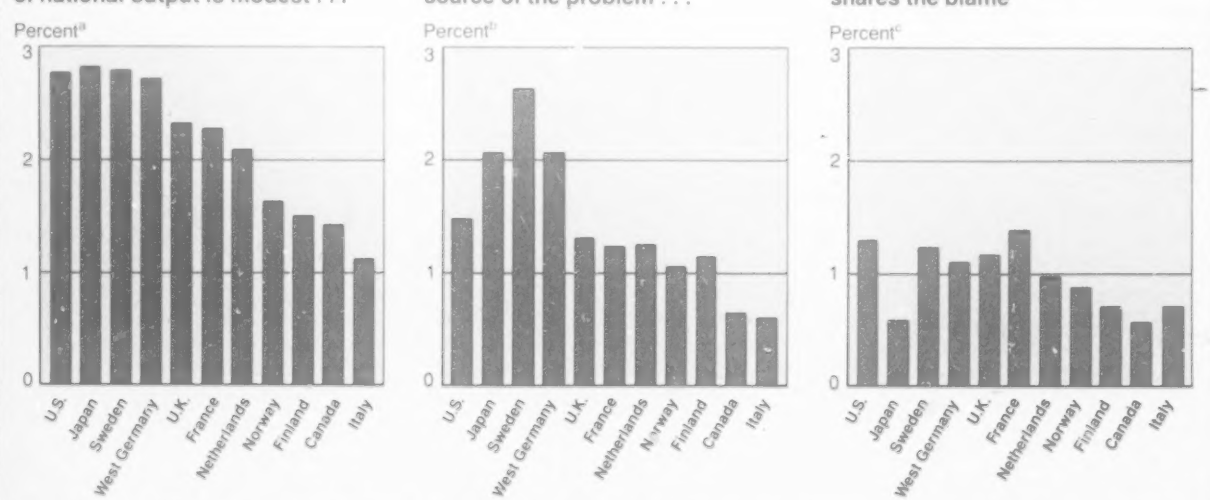
One explanation for this situation is that the Canadian domestic market is too small for companies to justify spending large amounts of money on R&D. This is especially true if the product line is not a good export candidate. Another is that Canada traditionally has tied its economic fortunes to its wealth of natural resources. And natural resource companies do not spend heavily on science and technology.

A more pervasive reason is that much of Canadian industry is owned by foreign companies, especially U.S. companies, which do the bulk of their R&D in their home countries and operate their Canadian subsidiaries as "branch plants." But Hugh C. Rowlinson, retired vice president for research and technology of C-I-L Inc., one of Canada's largest chemical companies, says this should be considered as positive, not negative as it's usually portrayed. It means, says Rowlinson, "that a great deal of research is available almost free."

Canadian industry, of course, has no one to blame but itself for the pittance it spends on R&D. But the government isn't blameless, either. The federal government directs a lopsided 62% of its total spending on science and technology to its own government laboratories. A miserly 16% or so goes to industry. And, although the government does support about 20% of industrial research in Canada (through grants, contracts, and tax measures), that is a small proportion compared with the U.S. and many other industrialized countries.

Regardless of where the blame lies, there's little argument that Canada will have to do a far better job on science and technology if it hopes to meet the high-tech competitive challenges that it faces. Former science minister Oberle says that government, indus-

Canada spends proportionately less on R&D than do most industrialized nations



a Gross expenditures on R&D as percent of gross domestic product (GDP), 1985 data. b Industry R&D spending as percent of domestic product by industry (industry's share of GDP), 1985 data, except Canada (1984). c Government R&D spending as percent of GDP, 1987 data, except Japan (1986). **Source:** Organization for Economic Cooperation & Development

Science policy and the Canadian chemist

Canadian chemists and chemical engineers are naturally concerned about the direction of science policy in Canada. And their views are just as diverse as those in any other scientific discipline. But they aren't particularly vocal about expressing them outside their own coterie. When it comes to telling government what they think about its policies, "We don't have a very active or vocal chemical science community in Canada," admits Anne Alper, executive director of the Chemical Institute of Canada (CIC).

CIC has not been very active in trying to influence science policy in Canada. It had been in the past, says Alper, and she'd like it to be again. In the meantime, CIC tends to be more reactive than active.

Although CIC certainly has budget problems, they are not why the institute hasn't been more outspoken on science policy. It has recently restructured itself into three separate groups under the CIC umbrella. The three are the Canadian Society for Chemistry, the Canadian Society for Chemical Engineering, and the Canadian Society for Chemical Technology. As a result, internal problems command much of CIC's attention. These are expected to be cleared up by next year, Alper says. Then, she adds, CIC will be able to devote more of its attention to external matters, such as science policy.

Three years ago, CIC was instrumental in forming the Action Committee of Science & Technology Presidents (ACSTP). This group of 20 presidents representing various Canadian science and technology societies formed a national lobby to fight for more federal investment in R&D. It intended to hire a professional lobbyist and set up an office to coordinate science policy activities on behalf of more than 100,000 scientists, engineers, and technologists.

But the presidents' action committee is no more. It died, says Alper, because nobody wanted to put their money where their mouths were.

To its chagrin, CIC also found itself in the eye of a hurricane of protest over a study that it helped sponsor. CIC, along with the Canadian Council of University Chemistry Chairmen, the Royal Society of Canada, and the Natural Sciences & Engineering Research Council (NSERC), commissioned a study to chart the future direction of chemistry in Canada, with an eye on the necessary money. The study was led by Howard Clark of Dalhousie University and James A. Morrison, who had previously been at McMaster University.

Their report, "Towards Excellence in Chemistry," was released in September 1986. Later, it became known as the Clark-Morrison report and later still simply as the Morrison report.

Before it was published, the seminal

try, and the universities will have to work together to make it happen.

If it's going to happen at all, Canada's new ISTC will play a leading role. Billed as a "flagship" for the government's economic development efforts, the department's primary focus will be on improving Canadian industry's ability to compete in international markets. To do its job, ISTC will try to strengthen the country's science and technology base, from the most basic research to technology, and all the way through innovation to marketing. ISTC sends a signal loud and clear—the effort to improve science and technology in Canada will have a definite industry focus.

Former ISTC minister de Cotret says that the department is the one that "will speak to, for, and about industry, science, and technology in the government of Canada." And there's little doubt that what ISTC does will help determine the fate of science and technology in Canada.

However, neither de Cotret nor Oberle will be there to guide ISTC, because of the major cabinet reshuffling last month, in which Andre became ISTC minister and Winegard replaced Oberle as Minister of State (Science & Technology). Canada's scientific community is still trying to assess these changes. Initial reaction is favorable. Both know the science beat (Andre is a chemical engineer and Winegard is a metallurgical engineer). If nothing else, they should certainly increase the awareness level of science and technology within government. The still-unanswered question is how this increased awareness will be translated into action.

Some Canadian scientists, especially in academia, worry that the government's emphasis on R&D will drop because the science minister is a junior minister whereas the ISTC minister is a senior minister. Doerr says they are afraid that, by identifying science so closely with industry, basic R&D will suffer. Others dismiss that point of view, saying that what's really important is that science and technology now have their own "portfolio," or department.

Even more important, says Kenney-Wallace, is how much "clout" the new ISTC team will have. The answer to that has not yet been determined, but based on the cabinet assignments that Andre has received, the betting is that he will be able to hold the line against cutbacks in science and technology spending. He may not, however, be able to pry additional R&D funds out of government.

The new ISTC department is only one block in the foundation that Mulroney's conservative government has been laying under Canada's science policy since it roared into office in 1984 with the largest parliamentary majority in Canadian history. Although improving Canadian performance in R&D and technological innovation was part of their agenda from the start, the Conservatives started out poorly in the eyes of the scientific community. Their first priority was reducing a heavy federal deficit. As a result, the fiscal axe fell hard on science and technology, with the toughest blows falling on the National Research Council, the government's own major laboratory.

After that, their science track record improved. First they scrapped the infamous scientific research tax

U.S. study, "Opportunities in Chemistry," or the Pimentel Report, appeared in the U.S. The Clark-Morrison committee relied heavily on the Pimentel Report's statistics and outlook, so much so that it was accused of being the "Canadian Pimentel Report."

That was the least of the report's problems. What shocked the Canadian chemical community were the report's recommendations. It contained nine recommendations, but the basic thrust was selectivity and excellence; that is, more support for the chemical elite at the expense of all others. The report suggested that, to award larger grants to the best researchers, NSERC should cut its number of individual grants 10% per year for five years. The objective: more support for the very best 200 to 300 Canadian chemical researchers.

After the initial shock wore off, the storm of protests began. The simplistic comparison of the U.S. and Canadian situations was the least of them. Most of the responses to the Morrison report condemned its recommendation that funds for the little guy be cut. And most of the responses came from the smaller universities that would suffer the most if the recommendations were implemented.

NSERC, the granting council that helped sponsor the Clark-Morrison study, rejected its proposals outright, saying that smaller chemistry departments had a role to play and should not be squeezed out of the research picture. In fact, none of the sponsoring organizations, including CIC, endorsed the report.

The report did succeed in initiating a lively debate on chemical science policy within the chemical community itself. But so far, there's no outcry for a new study to replace the Morrison report.

Despite the negative response that the Morrison report triggered, ironically some of its recommendations now are coming into play. The government's science policy is leaning toward excellence. Grants for chemical research are becoming more selective. All this has the small universities worried.

On the industrial side, the Canadian Chemical Producers Association (CCPA) has developed a policy paper on research, development, and innovation in the chemical industry. CCPA, says Art LeNeveu, its vice president for business development, thinks that the driving force for chemical innovation is the marketplace.

It has reservations about setting precise targets for R&D expenditures as a percentage of gross domestic product. That concept, says LeNeveu, doesn't take into account differences in a country's size or its market structure. Nor is the concept an appropriate guide for individual industries.

The focus of Canadian science policy should be on the entire innovative process, not just on R&D, according to CCPA. And CCPA doesn't want to see any "self-imposed" impediments placed on access to technology from foreign countries.

credit, a well-intentioned but administratively flawed R&D tax break for companies. It became known as the "$2 billion boondoggle" in Canada and soured an already complacent public on research and research workers.

In March 1987, the federal, provincial, and territorial science ministers signed Canada's first National Science & Technology Policy. The government calls it a "historic agreement." Others call it a "motherhood" statement of broad, general principles with no meat on its bones. That same month, the government launched InnovAction, which it billed as the Canadian Strategy for Science & Technology. It's primarily an umbrella catchphrase under which government has introduced some specific initiatives dealing with science and technology.

Oberle: have to work together to make it happen

Organizationally, the Mulroney government established the House of Commons Standing Committee on Research, Science & Technology. It also created a National Advisory Board on Science & Technology. Board members include leading scientists, educators, industrialists, and union leaders who assess national goals and policies for science and technology, again with an eye on their value to the Canadian economy.

However, the board's outstanding feature is that it is chaired by Prime Minister Mulroney himself. It's the first time that such a board has been chaired by a prime minister. It's also an unmistakable signal that the government is at least trying to improve the climate for science and technology in Canada.

Another strong signal came early last year, when Mulroney personally hosted a National Conference on Technology & Innovation in Toronto. More than 200 of Canada's scientific elite showed up at the by-invitation-only conference. Again, the conference theme was the challenge to Canada's competitive position in international markets and the importance of science and technology in meeting that challenge.

The government used the conference to announce a five-year, billion-dollar boost in government support for science and technology. Of that, $195 million (all figures in U.S. currency; $1.00 = $1.23 Canadian, 1988 average) was earmarked to establish a "centers of excellence" network.

With the program, patterned after a provincial program in Ontario, the government hopes to establish additional links among government, industry, and university researchers. The emphasis, as the name implies, will be on excellence—world-class research to improve Canada's international competitive position. Kenney-Wallace calls the Centers of Excellence

Canada's R&D performance doesn't stack up too well against other nations

	Canada's rank among eight countries[a]
Gross R&D spending as % of gross domestic product	Lowest
Industry-funded R&D[b]	Lowest
Government-funded R&D[b]	Second lowest
Government-performed R&D[b]	Middle
Higher education R&D[b]	Second lowest
Domestic patents granted[c]	Second lowest
International patents granted[c]	Lowest
Advanced degrees awarded[c]	Middle
Scientists and engineers in labor force[c]	Lowest
Number of technology-intensive industries with positive trade balance	Lowest

a Canada, France, Japan, the Netherlands, Sweden, U.S., U.K., and West Germany. b Adjusted for gross domestic product. c Adjusted for population. **Source:** National Advisory Board on Science & Technology

program "a bold experiment that will expose lab R&D to what's going on in the real world."

An international peer review system will screen applicants, but whether excellence or politics finally decides which projects will be funded remains to be seen. Competition for the limited funds is fierce. About 240 proposals have been submitted. Probably no more than 15 will be funded.

But the Centers of Excellence program has already accomplished something. It has thrown together people who never communicated with each other before. Vincent Wright, a keen observer of Canadian science and technology and editor of the newsletter *Research Money*, thinks that there will be a lot of winners among the many proposals that aren't selected. That's because, by simply collaborating on a proposal, groups of researchers have generated a momentum that won't completely disappear.

The Centers of Excellence program also underscores the government's intention to zero in on excellence in research—the rifle, rather than the shotgun, approach. Targeted research and focused research now are catchphrases in Canadian scientific circles. Yet, the "few versus the many" and the "equity versus efficiency" arguments have not disappeared in Canada. For every scientist who advocates showering most of the scarce funds on the cream of the scientific crop, there is another who says that they should be spread around equitably, regardless of the scientist's track record or stature.

Nor does everyone agree that the focus of supported R&D should be on the market payoff. That, along with an attempt to encourage companies to increase their R&D, is also the goal of a matching funds program. In it, the government matches industry dollar-for-dollar in supporting university research. Largely as a result of the program, private-sector funds to universities increased 18% in fiscal 1988.

But many university scientists are uneasy about the direction in which science policy is heading in Canada. They believe that the government is trying too hard to force a collaborative effort between universities and industry. This approach gives short shrift to basic research, which is, or should be, the major concern of science in universities. As a result, there lurks the danger of conflicting roles.

Another complaint about the matching funds program is that it favors those universities, usually the larger ones, that already have well-established contacts with industry. The smaller schools that have little or no experience collaborating with industry will get the leftovers, if there are any. The complaint goes that it's always easier to nurture existing programs than it is to start new ones. But it's inevitable that there will be more emphasis on university-industry collaboration. It's an inherent part of the government's game plan.

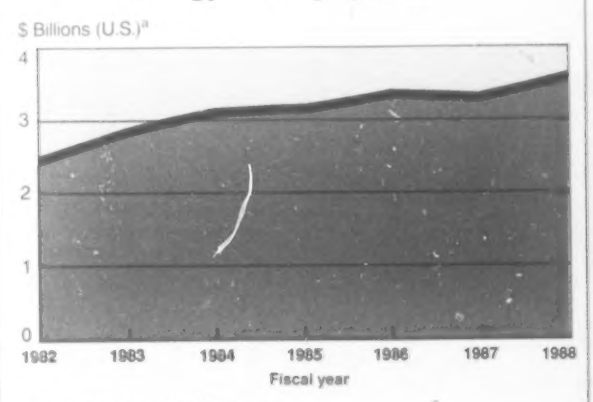
The trend disturbs many university scientists, who feel that the universities are being transformed into the handmaidens of industry. They also are afraid that funding for basic research will suffer.

Most university research money comes from the so-called granting councils. Of the three—the Natural Sciences & Engineering Research Council (NSERC), the Social Sciences & Humanities Research Council, and the Medical Research Council—NSERC has by far the largest budget and is the most critical to university research.

NSERC's budget has increased an average 3.3% per year since 1984, hardly enough to keep up with inflation. Last year, its budget was $289 million. However, most of the increase came through the matching funds program. Its base budget has remained virtually level. The council always has more university researchers clamoring for money than it can possibly handle. In fiscal 1986, NSERC made more than 6000 operating grants, but the average was a weak $18,700.

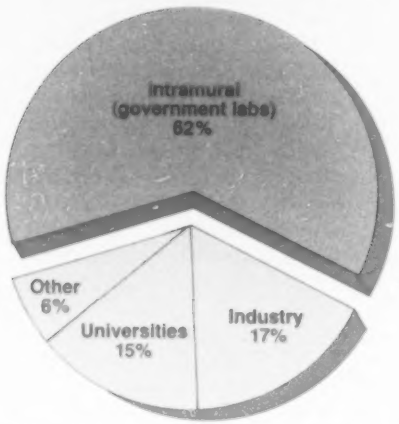
Many in industry believe that, with the exception of their top guns, universities are getting about as

Canadian federal spending on science and technology inching upward



a $1.00 = $1.23 Canadian, 1988 average.
Source: Industry Science & Technology Canada

Canadian government spends most science, technology funding in own labs



Canadian federal government expenditures on science and technology, fiscal 1988 = U.S. $3.58 billion[a]

a $1.00 = $1.23 Canadian, 1988 average
Source: Industry Science & Technology Canada

much research money as they can usefully put to work. About 25% of NSERC's operating funds go to only 10% of the top university researchers.

What universities are desperately short of are overhead funds. The federal government will support research, which means primarily salaries and some equipment. It will not pay university overhead costs, such as maintaining existing buildings, building new ones, or providing services that cannot be allocated to any one research project.

One reason is that, under the Canadian constitution, education is a provincial responsibility. The federal government dare not intrude. In Canada, the debate over the division of power between federal and provincial governments is a national pastime. University education and R&D programs often suffer as a result. It's a big problem, but some provinces are beginning to tackle it.

In fact, some provinces are jumping feet first into their own science and technology programs. Ontario had a Centers of Excellence program before the federal government did. It also has an R&D tax benefit program, which will allow companies large tax write-offs on their research investments. And Quebec recently said that it would boost its support of science and technology by $1.13 billion over the next five years. The program includes tax-based incentives, a new technology fund, and a government procurement program designed to stimulate R&D.

Ontario and Quebec are the centers of advanced technology in Canada and have the most ambitious programs to support science and technology. But most other provinces either have similar programs or are considering them. The danger is that, in going their own way, each province may bite off more than it can chew and spread its funds over too many categories of science and technology. "All of them can't be good at all things," says Wright. Nor, he adds, should they.

Rowlinson thinks the direction that both the provinces and the federal government are taking is basically correct. But, he says, "There will always be room for endless discussion on how much money should be allocated."

Canada's budget deficit and debt will command the government's attention immediately. The deficit is running almost 5% of the country's gross domestic product, and the public debt has now reached $260 billion. That's about 54% of gross domestic product, substantially higher than the 40% that it was in 1984. Clearly, Canada's fiscal health is poorer in 1989 than it was five years ago.

The question is not how much more money will be allocated to science and technology. It's more likely to be how to keep in the science and technology envelope the money that's already there. ISTC's Doerr doesn't expect cuts. She thinks that money for science and technology is about as low as it can go.

Regardless of whether she is correct, the next question is how the funds will be allocated. Some policymakers favor reallocation. It is a strong possibility.

The most logical place to look for "spare" money to reallocate is the government's "intramural" R&D funding; that is, its own laboratories. In the current fiscal year, they will receive $2.2 billion, or a hefty 62% of the government's science and technology budget. By some reckoning, they perform only 22% of the country's research. Shifting even 10% of that $2.2 billion would release a sizable $220 million, presumably to the universities.

The federal government's own National Research Council (NRC) is the focus of a lot of attention—and argument. NRC is Canada's largest and most diversified research group, although it does not have the clout that it had in its glory days following World War II. The council has suffered more fiscal damage from government cost cutting over the past several years than any other area of science and technology. Its budget now is only $390 million.

Photo by Yousuf Karsh

Kenney-Wallace: Centers of Excellence a bold experiment

That's only about 18% of the government's spending on intramural science and technology. The rest is consumed in the various "mission-oriented" ministries, such as Agriculture, Environment, and Energy, Mines & Resources.

The large proportion of a government's R&D money going to its own labs is unique to Canada. The country must come to grips with such a lopsided in-house R&D effort. The government has been cutting in-house R&D spending, but more of it is in order. If any money is reallocated, basic R&D at the universities likely would benefit most. If those hard choices have to be made, Kenney-Wallace says that "It is up to us in the business of shaping policy to make sure that existing funds are reallocated into the university R&D base without disrupting existing programs."

But the problems Canada faces with science and technology go beyond just shifting research dollars or nudging research into the areas that will yield the most economic benefit. A major shortcoming is that there is no groundswell of public demand for spending a lot of money on science and technology. To the Canadian in the street, there's no sense of urgency. Life is good. Each has ideas of what the government's agenda should be. Science and technology do not rate high on those agendas. One reason: they remember the $2 billion research tax boondoggle.

Paul Dufour, a former policy analyst at ISTC now on temporary assignment in External Affairs Canada's science and technology division, puts it bluntly. "We don't have a science culture in Canada," he says. Adds Oberle, "Canadians do not yet fully appreciate the significance of the fundamental shift we are experiencing from a resource-based economy to a knowledge-based economy."

To Oberle, one of the greatest challenges facing Ottawa is to make the public more aware of the role that science and technology must play in shaping the country's future. Last year, the government took some very small steps to meet that challenge. It allocated first $8 million, then another $2 million to a program called Science Culture Canada. The money will help to sponsor projects and programs organized by nonprofit groups and a public awareness campaign involving the public and private sectors. It also will help publicize major achievements in Canadian science and technology.

Still another problem is obtaining quality graduate students to foster quality university research. The problem is especially acute in the lesser known schools, away from urban areas. Underlying the problem is that too few undergraduate science students go on to graduate work and that too few high school students choose science and engineering when they hit the universities.

The government has responded with a five-year, $65 million Canada Scholarship Program designed to encourage outstanding high school students to pursue careers in science. But it's only a drop in what the bucket needs.

Perhaps Canada wouldn't have to worry so much about its science and technology policy if it relied more on imported technology. The possibility of following Japan's example hasn't gone unnoticed—or unchampioned: Buy imported technology for Canada, rather than struggle to develop technology in Canada.

Those who advocate such an approach worry that Canada, with its small population and small number of scientists, is spreading its research talent and funds over too wide a base. They say that the country could use its scarce resources better by targeting them at technological areas that Canada absolutely must develop, and buying the rest from other countries.

To some extent, this already is being done. But most experts don't believe that this is the solution to Canada's future economic success. Using someone else's technology usually forfeits to them a two- to three-year lead time to the market. And by the time Canadian industry adapts to the foreign technology it bought, newer and better technology would be available to take its place.

So the quest for a science policy in Canada will continue. The prestigious C. D. Howe Institute, a Canadian nonprofit economic research organization, published a report last month reviewing government policy since 1984 and its possible course over the next few years. The report concludes that the Conservative's accomplishments on science policy since 1984 were "modest." It concedes that the government has at least formed a consensus on the approach to take. But because of fiscal problems, it has not done much to increase funding.

This is not necessarily bad, says the Howe report, because improving the quality and results of Canada's R&D is more important than blindly throwing more money at the problem. And it applauds the government's efforts to forge more government-industry-university linkages. But, says the report, these steps, although promising, "do not yet constitute a viable new approach to science and technology policy in Canada."

The report recommends that a continuing effort to develop a "market-driven" science and technology strategy should be a priority on Mulroney's agenda. Despite some misgivings among scientists, it probably will be.

Throwing money at science and technology may not be the complete answer, but almost everyone agrees that more money wouldn't hurt. They believe that government should look upon science and technology as an investment, not a cost. However, faced with the twin problems of a budget deficit and a huge national debt, the chances that government will appropriate more is slim. The alternative is to reallocate existing funds to get the most mileage out of them. And that's certain to keep the kettle of debate boiling.

It may be next to impossible to get universal agreement on any one science policy in Canada. But, says Wright, it's always hard to reach agreement in Canada. "We can't even agree on a bloody constitution."

Nevertheless, Kenney-Wallace believes that science and technology has now become firmly entrenched as a central part of policy-making in Ottawa. But she calls the next few years the era of hard choices. "There are," she says, "no soft ones left." □

Middle East Chemical Industry Eyes New Products, Markets

Persian Gulf petrochemical industry turns to polymers, fibers, other sectors as it seeks end to dependence on oil, first-generation derivatives

Patricia L. Layman, C&EN London

Nearly 60 delegates met in Manama, Bahrain, late last month to discuss a topic they were all keenly interested in—the petrochemical industry. Basking in the warming late-winter temperatures on this island in the Persian Gulf, dodging a rare but welcome rain shower and high winds that kicked up a foglike haze of sand through Bahrain's capital city, the delegates tackled the topic of Middle East energy and chemicals.

This was the second such seminar sponsored by London-based consultants Chem Systems International. And it built on the philosophy of last year's seminar, to provide a forum for the exchange of ideas between senior personnel both from within the region and from other parts of the world. There were representatives from Arab/Gulf organizations—industrial, governmental, and financial; from Japanese companies and banking consortiums; and from a few assorted western chemical companies.

And just as sand and clay are evolving into sleek high-rise concrete and glass, changing the skyline of Manama, so the petrochemical industry in the Gulf region is working to change from a historical dependence on oil and its first-generation derivatives to the construction of sophisticated downstream businesses in polymers, fibers, and similar sectors. Although phrases such as "Green Party" or "Green politics" may still be unfamiliar to the Gulf, the industry is even tackling the topic of environmentalism, with governmental encouragement.

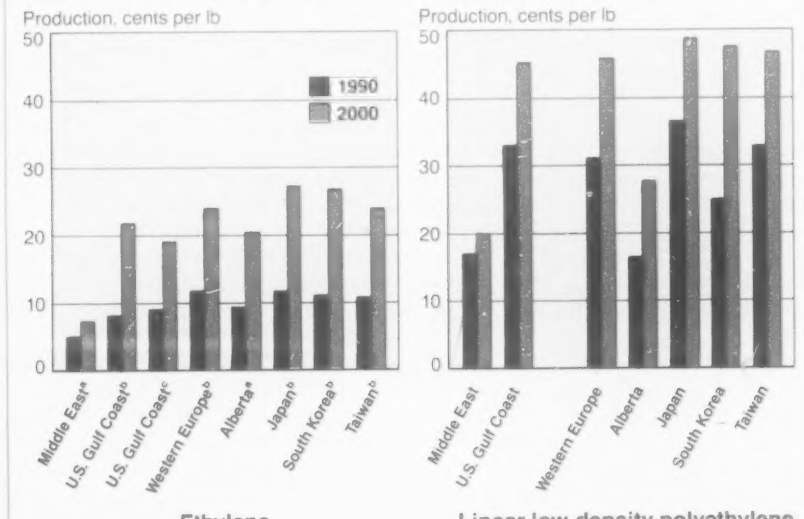
For example, keynote speaker Sheikh Isa bin Abdulla al-Khalifa, undersecretary for Bahrain's Ministry of Development & Industry, brought up the subject, in addition to the business-cycle side of petrochemicals. "Things are good—sales are good, with shortages of capacities," he says. "New projects are being announced, and so on. But how long can the good times last? Have the seeds for future difficulties been sown?"

Several companies are moving toward marketing of new petrochemical products based on scientific research that can be sold for high prices, with applications in a wide variety of uses, he points out. "It is hoped this will lessen vulnerability to the cycles in the petrochemical industry. Even the biggest companies realize the value of a balanced portfolio, with bulk materials and high-value-added products, such as engineering plastics."

An important question that had to be faced, however, was environmental. Sheikh Isa's challenge to industrialists and financiers alike was, "With the surge into plant production, will sufficient attention be given to environmental issues, such as waste emissions, and disposal of wastes, such as plastic wastes?"

Indicative of the growing environmental awareness in the Gulf region, the editorial page of the local paper, the *Gulf Daily News*, applauded Sheikh Isa's concern the day after his address. "The effect of environmental pollution from petrochemical plants, or any other in-

Middle East will stay low-cost producer of ethylene, linear low-density polyethylene through end of century



a Ethane feedstock. b Naphtha feedstock. c Propane feedstock. **Source:** Chem Systems International

dustrial complex, is an important issue," the editorial read. "Important as it is to any national economy, industry has a duty to safeguard the health of its workers, nearby residents, and the environment in general. Irresponsible action now will only leave a cruel legacy for future generations, creating a pollution time bomb, to explode in years to come," the editorial concluded.

If environmental awareness is one of the hallmarks of a sophisticated petrochemical industry, it will certainly become more significant in the Gulf region over the next decade. For the Gulf's petrochemical industry—already a major industry in Saudi Arabia—is poised to grow quickly.

At least it will if the recommendations of the Qatar-based Gulf Organization for Industrial Consulting (GOIC) are taken up by the various governments in the region, which basically include Iraq, Kuwait, Bahrain, Qatar, Oman, Saudi Arabia, and the United Arab Emirates, which includes Abu Dhabi and Dubai.

At present, said Abdullah Hamad al-Moajil, secretary general of GOIC, the Gulf's percentage of world petrochemical production varies significantly by chemical. For example, of total world methanol production of 18.4 million metric tons in 1987, the Gulf accounted for 9.4%, and in 1990 that percentage is expected to hit 10.1% of total world production of 22.9 million metric tons. The Gulf's share of ethylene production in 1987 was 4.4% (of total world production of 54.6 million metric tons), and will rise in 1990 to 5.4% (of total world production of 70.6 million metric tons). Similarly, its contribution of 4.0% of world polyethylene production of 28.5 million metric tons in 1987 will rise to 4.4% of a 1990 total of 33.2 million metric tons.

On the other hand, the Gulf is low in aromatics production, he says. The region accounts for 0.1% of the world's production of toluene (world total of 14.3 million metric tons in 1987), and the percentage is expected to remain the same as world production grows to 14.9 million metric tons in 1990. The region is boosting production of benzene, however; in 1987, the Gulf accounted for only 1% of world production of 26.3 million metric tons, but that will grow to 2.6% of total production of 29.9 million metric tons in 1990.

The region had two advantages on which to base its competitiveness: the availability of long-term supply of local feedstock, especially natural gas, and lower cost feedstock and utilities. "The region pretty much decided that the best thing to do with natural gas was to industrialize, not take a course like Algeria, with its liquefied natural gas," says Al-Moajil.

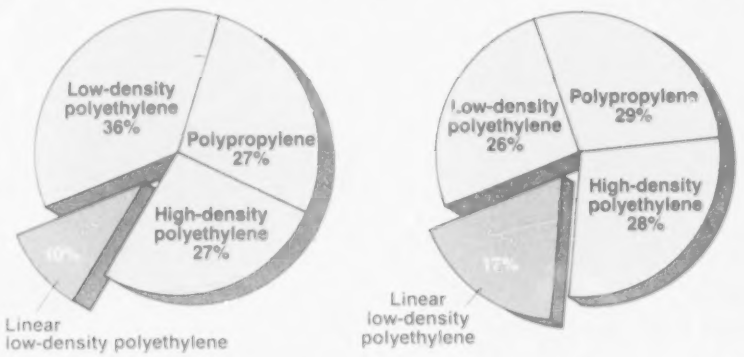
Using natural gas as a feedstock would give the region a solid base to build on. According to GOIC's figures, the Gulf region accounts for 14.1% of the world's natural gas reserves, with a number of countries—Abu Dhabi, Iraq, Kuwait, Oman, Qatar, and Saudi Arabia—having reserves estimated to last for more than 100 years.

GOIC's strategy regarding new projects covers several points. New projects, the consulting group says, should meet existing and expected world consumption, should capitalize on restructuring trends throughout the industry, and should use any relative advantage to compete with less advantaged existing facilities elsewhere in the world. The last two points cannot be separated, Al-Moajil says. "If there are less advantaged facilities, these should be closed down."

With those assumptions in hand, GOIC has recommended a variety of new projects that should be built immediately in the Gulf. It has also put together a list of other projects it feels should be built in the Gulf region sometime in the next 10 years.

For example, Naji Atallah, projects director of GOIC, says the time is

LLDPE's share of market to grow fastest through mid-'90s



Source: Chem Systems International

Polyethylenes top Middle East capacity and demand

Thousands of metric tons per year	1985		1990		1995	
	Capacity	Local demand	Capacity	Local demand	Capacity	Local demand
LDPE	414	265	454	335	514	380
LLDPE[a]	510	36	560	75	550	95
HDPE[a]	230	110	470	180	600	220
Polypropylene	60	147	60	190	445	230
PVC	185	320	415	440	490	560
Polystyrene	25	95	150	160	240	220

Note: Includes Turkey, excludes Egypt. LDPE = low-density polyethylene, LLDPE = linear low-density polyethylene, HDPE = high-density polyethylene, PVC = polyvinyl chloride. a Swing capacity (capacity can be used for either HDPE or LDPE). Source: Chem Systems International

Consultants see Middle East expansion opportunities

	Recommended for immediate implementation		Recommended over next 10 years
	Total capacity, thousands of metric tons per year	Location	Total capacity, thousands of metric tons per year
Methanol	1500	Qatar, Oman, and United Arab Emirates	
Propylene	200	Bahrain	800–1000
Urea			3000
Polypropylene	100	Bahrain	500–800
Propylene oxide	80	Saudi Arabia or Bahrain	80–100
High-density polyethylene	90	Qatar	
Toluene	40	Saudi Arabia	
***p*-Xylene**	32	Saudi Arabia	
***o*-Xylene**	40	Saudi Arabia or Iraq	
Styrene-butadiene rubber	40	Saudi Arabia	
Nylon	40	Saudi Arabia or Iraq	
Dinitrotoluene	10	Iraq	
Toluene diisocyanate	40	Saudi Arabia or Iraq	
Terephthalic acid	50	Saudi Arabia	
Polyester	50	Saudi Arabia	
Phthalic anhydride	40	Saudi Arabia or Iraq	
Petroleum coke	300	Bahrain, Kuwait, or United Arab Emirates	
Acetic acid	80	Saudi Arabia, Qatar, or Bahrain	
Formaldehyde	30	United Arab Emirates, Saudi Arabia, or Bahrain	
Lube oil additives	35	United Arab Emirates and/or Saudi Arabia	
Acrylic fibers			50–70
Butene and butadiene			100
Isobutene			15–20

Source: Gulf Organization for Industrial Consulting

right for Bahrain to go ahead with a $200 million polypropylene plant "as soon as possible. It is the perfect time, because polypropylene is a growing market and the product is in very high demand." In fact, consulting engineering company Bechtel is doing a feasibility study for the Bahrain government for a plant that would produce between 100,000 and 200,000 metric tons a year, fed with propane.

Of course, other Gulf countries, including Saudi Arabia and Kuwait, are planning similar plants. High world prices, boosted by heavy demand, mean the cost of a new plant could be paid off in two years, predicted David F. Oxley and Geoff Pyke, Chem Systems directors, at the seminar.

The Middle East also has investment opportunities in such downstream products as methyl *tert*-butyl ether (MTBE). Pyke points out that the real importance of MTBE relates to its value as a substitute for other octane enhancers, such as tetraethyl lead and benzene, in the production of gasoline.

The market potential for the compound is dramatic. According to Chem Systems data, just concentrating on the U.S. and Western Europe, the consumption of MTBE as a gasoline additive is currently more than 4 million metric tons per year. This market could reach 15 million metric tons by 1995, two thirds in the U.S., one third in Western Europe. MTBE demand in the U.S. could be nearly 10 million metric tons per year by 1995, says Pyke, but domestic supply is unlikely to be much higher than 3 million metric tons, so imports will have to be substantial. Similarly, in Western Europe, demand in 1995 will be about 5 million metric tons, met largely by imports. Much of the imported product—into either region—will come from new projects.

MTBE certainly offers further investment potential for the Middle East, given projected demand growth and need for additional capacity, Pyke says. The region already has a ready availability of feedstocks. And current pricing developments will favor the butanes route. Of course, he adds, negative factors exist, including the substantial capital investment required by a field butanes project, and the uncertainty of the MTBE price outlook.

MTBE plants will find solid export markets, in a variety of geographical regions. However, some caution may be needed in building up investment in other export-oriented products, because a major export destination, the Far East, is building itself up, warns Alan Plaistowe, Chem Systems president.

The Far East has traditionally been a market for exports from Western Europe and the Middle East. Notes Plaistowe: "The East Asian market is an extremely important one to producers in other areas of the world and has served as the preeminent target market for trade during the 1980s." That worked during the surplus years of the early and mid-1980s, he says, but when capacities turned snug and producers concentrated on supplying domestic markets, supplies to the East Asian countries tapered off and prices rose—"significantly higher than could be found in the domestic markets of the U.S. and Western Europe."

Those high prices, however, increased the interest and determination of producers of petrochemicals in Asia to expand capacities. The result is a significant growth of petrochemical investment in South Korea, Taiwan, and Southeast Asia, particularly Thailand.

The Middle East and the U.S. most likely will become the swing suppliers—East Asia will look to these areas to supply incremental volumes. The Middle East, especially, should stand to benefit. This is due to the competitive cost advantages Chem Systems believes the Middle East has and will continue to have through the end of the 1990s, with production costs significantly lower than those elsewhere. □